Forest Health Protection

Northeastern California Shared Services Area
2550 Riverside Drive, Susanville, CA 96130

Sheri L. Smith
Supervisory Entomologist
ssmith@fs.fed.us
530-252-6667

Daniel R. Cluck
Entomologist
dcluck@fs.fed.us
530-252-6431

Special Project Report

Date: February 4, 2005
File Code: 3440

35.97854,-118.43571

To: District Ranger, Cannel Meadow Ranger District, Sequoia National Forest

Subject: "Effects of Fire Injury on Survivability of Conifers" (NE-SPR-05-04)

Thank you for allowing Forest Health Protection (FHP) to implement and continue monitoring fire-injured trees in the 2002 McNalley Fire. We greatly appreciated the cooperation of District personnel in setting up the study. Our current District contact for the project is Pat Dauwalder. Enclosed please find a copy of the original study plan, a map of tree locations and a summary of data collected from 2003 and 2004.

As part of this project, 3,918 trees are being monitored through 2005 or longer if funds are available. Individual study trees have a numbered metal tag at the base that corresponds with an orange painted number at breast height. Trees also have two bands of orange paint around their circumference (please note that some of the orange paint may have faded to white). Please continue to notify us if there is a need to remove study trees that have died. Verification of full crown fade and the tree number are required prior to tree removal.

Data for all FHP fire-injured tree survivability studies are currently being analyzed. A presentation at the National Silvicultural Workshop (June 2005, Lake Tahoe) is planned followed by a publication in the conference proceedings. Please contact us if you have any questions or concerns.

/s/ Danny Cluck

Danny Cluck
Entomologist

/s/ Sheri Smith

Sheri Smith
Supervisory Entomologist

Summary of Data for the 2002 McNalley Fire

Table 1. Total number of trees and mortality by year.

Species	# of Trees	2003 Mortality	2004 Mortality	Total Mortality
Ponderosa/Jeffrey (Yellow) Pine	1232	415	390	805
White fir	1895	208	730	938
Incense Cedar	791	24	70	94
TOTAL	**3918**	**647**	**1190**	**1837**

Table 2. Number of trees by percent remaining live crown volume.

Live Crown (%)	Incense Cedar	Yellow Pine	White Fir
0<10	68	130	338
10<20	83	321	410
20<30	76	208	362
30<40	59	222	297
40<=50	121	196	284
>=70	366	153	204

Table 3. Number of trees by cambium damage rating.

Cambium Damage Rating	Incense Cedar	Yellow Pine	White Fir
0	118	91	244
1	138	191	420
2	198	297	518
3	196	310	404
4	141	342	309

- Rating of 0-4 is based on a cambium sample taken in each of four equally spaced directions near ground level. A rating of 0 is equal to no fire damage for any sample and 4 is dead cambium at each sample location.

Table 4. Number of trees by diameter breast height.

DBH (inches)	Incense Cedar	Yellow Pine	White Fir
10<20	504	20	690
20<30	171	571	817
30+	116	641	388

Incense Cedar Survival (10<20"dbh)

Table 5. Total # of trees and # alive as of 2004 by cambium and crown classes combined.

% Volume Live	Cambium Damage Rating									
	0		1		2		3		4	
	N	# alive	N	# alive	N	# alive	N	# alive	N	# alive
0<10	1	0	6	0	10	4	9	2	20	3
10<20	3	3	10	8	16	13	17	13	8	6
20<30	8	8	6	5	13	13	19	16	9	6
30<40	8	8	4	4	10	10	13	12	10	6
40<=50	16	16	16	16	24	23	18	18	13	8
>=70	42	42	47	47	50	50	45	44	22	20

Table 6. Percent survival as of 2004 by cambium and crown classes combined.

% Volume Live	Cambium Damage Rating				
	0	1	2	3	4
0<10	0%	0%	40%	22%	15%
10<20	100%	80%	81%	76%	75%
20<30	100%	83%	100%	84%	67%
30<40	100%	100%	100%	92%	60%
40<=50	100%	100%	96%	100%	62%
>=70	100%	100%	100%	98%	91%

Incense Cedar Survival (20+"dbh)

Table 7. Total # of trees and # alive as of 2004 by cambium and crown classes combined.

% Volume Live	Cambium Damage Rating									
	0		1		2		3		4	
	N	# alive	N	# alive	N	# alive	N	# alive	N	# alive
0<10	2	0	5	1	3	1	5	1	6	0
10<20	1	0	3	3	6	4	8	5	4	3
20<30	2	2	3	3	5	5	7	7	8	8
30<40	0	0	1	1	4	4	3	3	6	6
40<=50	4	4	6	5	6	6	11	11	7	7
>=70	24	24	29	29	48	48	37	37	22	21

Incense Cedar Survival (20+"dbh) cont.

Table 8. Percent survival as of 2004 by cambium and crown classes combined.

% Volume Live	Cambium Damage Rating				
	0	1	2	3	4
0<10	0%	20%	33%	20%	0%
10<20	0%	100%	67%	63%	75%
20<30	100%	100%	100%	100%	100%
30<40	N/A	100%	100%	100%	100%
40<=50	100%	83%	100%	100%	100%
>=70	100%	100%	100%	100%	95%

White Fir Survival (10<20"dbh)

Table 9. Total # of trees and # alive as of 2004 by cambium and crown classes combined.

% Volume Live	Cambium Damage Rating									
	0		1		2		3		4	
	N	# alive	N	# alive	N	# alive	N	# alive	N	# alive
0<10	13	3	14	1	26	3	28	5	28	3
10<20	17	2	27	9	34	15	33	9	34	5
20<30	15	10	32	24	42	34	32	16	22	8
30<40	13	13	13	13	30	27	17	13	14	6
40<=50	20	19	32	30	30	27	19	14	17	16
>=70	13	13	17	17	33	33	10	10	11	9

Table 10. Percent survival as of 2004 by cambium and crown classes combined.

% Volume Live	Cambium Damage Rating				
	0	1	2	3	4
0<10	23%	7%	12%	18%	11%
10<20	12%	33%	44%	27%	15%
20<30	67%	75%	81%	50%	36%
30<40	100%	100%	90%	76%	43%
40<=50	95%	94%	90%	74%	94%
>=70	100%	100%	100%	100%	82%

White Fir Survival (20<30"dbh)

Table 11. Total # of trees and # alive as of 2004 by cambium and crown classes combined.

% Volume Live	Cambium Damage Rating									
	0		1		2		3		4	
	N	# alive	N	# alive	N	# alive	N	# alive	N	# alive
0<10	13	2	25	0	40	2	40	2	30	1
10<20	23	2	41	12	42	5	46	12	29	1
20<30	21	15	31	12	31	19	21	11	30	10
30<40	13	10	37	25	38	34	21	14	28	17
40<=50	13	11	27	26	39	34	23	18	14	9
>=70	10	10	17	17	23	23	24	24	12	10

Table 12. Percent survival as of 2004 by cambium and crown classes combined.

% Volume Live	Cambium Damage Rating				
	0	1	2	3	4
0<10	15%	0%	5%	5%	3%
10<20	9%	29%	12%	26%	3%
20<30	71%	39%	61%	52%	33%
30<40	77%	68%	89%	67%	61%
40<=50	85%	96%	87%	78%	64%
>=70	100%	100%	100%	100%	83%

White Fir Survival (30+"dbh)

Table 13. Total # of trees and # alive as of 2004 by cambium and crown classes combined.

% Volume Live	Cambium Damage Rating									
	0		1		2		3		4	
	N	# alive	N	# alive	N	# alive	N	# alive	N	# alive
0<10	12	0	19	0	29	3	13	1	5	0
10<20	10	1	23	0	23	5	10	0	14	1
20<30	15	3	17	3	19	10	15	2	9	4
30<40	12	9	20	11	18	14	16	8	4	3
40<=50	3	0	13	8	9	7	14	11	6	2
>=70	2	2	8	8	7	7	15	14	1	1

White Fir Survival (30+"dbh) cont.

Table 14. Percent survival as of 2004 by cambium and crown classes combined.

% Volume Live	Cambium Damage Rating				
	0	1	2	3	4
0<10	0%	0%	10%	8%	0%
10<20	10%	0%	22%	0%	7%
20<30	20%	18%	53%	13%	44%
30<40	75%	55%	78%	50%	75%
40<=50	0%	62%	78%	79%	33%
>=70	100%	100%	100%	93%	100%

Yellow Pine Survival (20<30"dbh)

Table 15. Total # of trees and # alive as of 2004 by cambium and crown classes combined.

% Volume Live	Cambium Damage Rating									
	0		1		2		3		4	
	N	# alive	N	# alive	N	# alive	N	# alive	N	# alive
0<10	1	0	4	0	8	0	7	0	17	0
10<20	17	5	18	0	36	8	45	5	51	2
20<30	2	0	11	5	22	6	26	4	32	5
30<40	8	4	22	19	32	14	27	13	27	14
40<=50	11	6	17	9	20	14	22	13	15	6
>=70	6	6	13	11	20	20	15	12	9	8

Table 16. Percent survival as of 2004 by cambium and crown classes combined.

% Volume Live	Cambium Damage Rating				
	0	1	2	3	4
0<10	0%	0%	0%	0%	0%
10<20	29%	0%	22%	11%	4%
20<30	0%	45%	27%	15%	16%
30<40	50%	86%	44%	48%	52%
40<=50	55%	53%	70%	59%	40%
>=70	100%	85%	100%	80%	89%

Yellow Pine Survival (30+"dbh)

Table 17. Total # of trees and # alive as of 2004 by cambium and crown classes combined.

% Volume Live	Cambium Damage Rating									
	0		1		2		3		4	
	N	# alive	N	# alive	N	# alive	N	# alive	N	# alive
0<10	3	1	15	0	18	0	21	0	34	0
10<20	11	0	23	0	26	0	39	0	44	1
20<30	6	1	14	1	34	2	28	5	21	2
30<40	10	4	14	6	18	7	20	7	29	6
40<=50	7	5	16	9	30	11	29	13	26	5
>=70	7	7	18	18	23	22	18	16	19	19

Table 18. Percent survival as of 2004 by cambium and crown classes combined.

% Volume Live	Cambium Damage Rating				
	0	1	2	3	4
0<10	33%	0%	0%	0%	0%
10<20	0%	0%	0%	0%	2%
20<30	17%	7%	6%	18%	10%
30<40	40%	43%	39%	35%	21%
40<=50	71%	56%	37%	45%	19%
>=70	100%	100%	96%	89%	100%

Figure 1. Relationship of cambium and crown damage to percent survival (20<30" dbh white fir example)

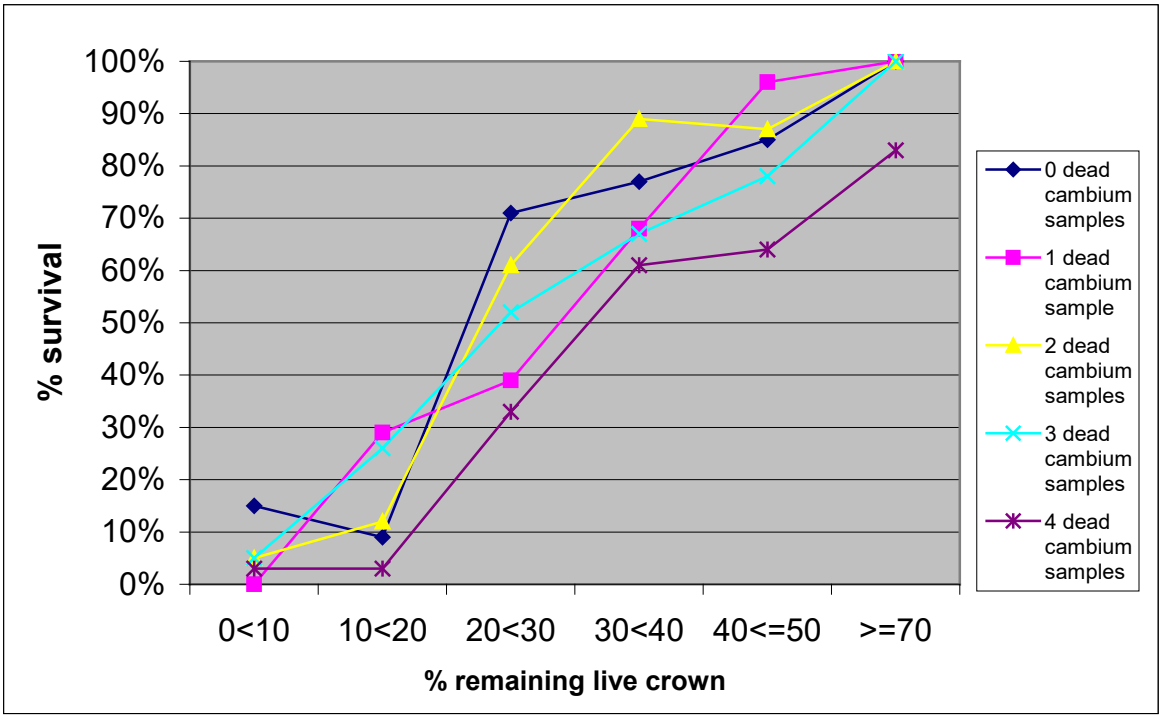
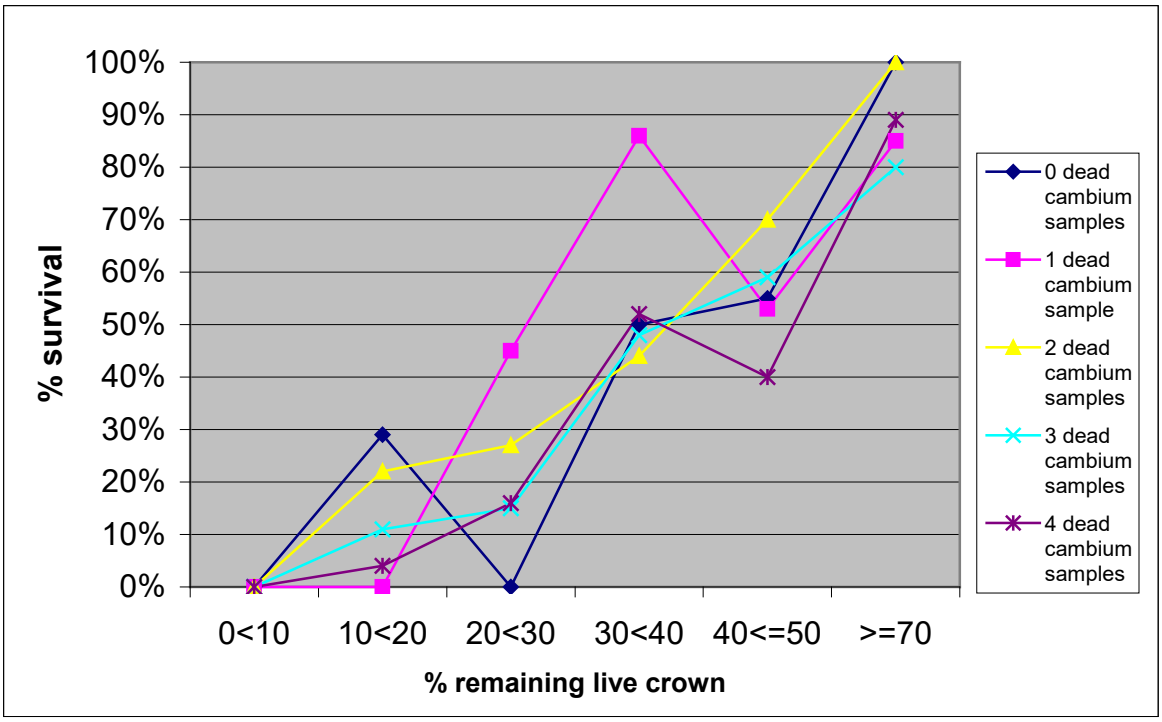


Figure 2. Relationship of cambium and crown damage to percent survival (20<30" dbh yellow pine example)



EFFECTS OF FIRE INJURY ON
SURVIVABILITY OF CONIFERS IN CALIFORNIA

This project will address the primary objective of improving post-fire management decisions regarding the use and accuracy of marking guidelines.

Specifically we will:

- Create mortality probability curves for ponderosa pine and Jeffrey pine (combined as yellow pine), white fir, and incense cedar three growing seasons after wildfire as a function of tree diameter, amount of cambium kill and the amount of tree crown killed by fire.

Background and Need

Prior to 2000, fire-salvage marking guidelines used throughout California were based on a paper by Willis Wagener (1961). There have been numerous other publications (Bevins 1980; Reinhardt & Ryan 1988; Ryan 2000; Ryan & Frandsen 1991, Lynch 1959, Petersen 1985) involving fire damage and tree mortality, however, Wagener's is the only work conducted in California. In 1995, following the Barkely Fire (burned in 1994, Lassen NF) and the Crystal Fire (burned in 1994, Tahoe NF), Forest Health Protection (FHP) staff located in Susanville, CA initiated studies to attempt to validate Wagener's marking criteria. Several FHP monitoring studies (Table 3 of Appendix A) have followed providing the basis for the current marking guidelines (Appendix A) initially developed in 2000.

The fire season of 2002 provided an opportunity to obtain data to expand our current knowledge base and continue to improve the accuracy of predicting fire damaged tree mortality. Data gaps

exist in the previous work by FHP due to inadequate sample sizes for some species, size classes, crown damage classes, and cambium kill classes present in previous fires. We intend, through this project, to substanially supplement our data base and build mortality prediction curves that can be used to modify the current guidelines. Data collected and analysed in this project will improve the accuracy of various fire damage and insect attack criteria used for predicting tree mortality.

Deliverable: The resulting mortality probability curves would, as a minimun, predict post wildfire mortality by the end of the 3rd growing season as a function of species, size class, crown kill class and cambium kill class. Additional independent variables may also be tested.

Cooperators:

Sheri Smith, Supervisory Entomologist, State and Private Forestry, Forest Health Protection, Northeast California Shared Service Area, Susanville, CA.

Kevin C. Ryan, PhD., Project Leader, Fire Effects, Fire Sciences Laboratory, Missoula, MT

Daniel Cluck, Entomologist, State and Private Forestry, Forest Health Protection, Northeast California Shared Service Area, Susanville, CA.

Sharon M. Hood, Forester, RMRS Fire Sciences Laboratory, Missoula, MT.

Mike Landram, Regional Silviculturist, Region 5, U.S.F.S. Pacific Southwest Region, Vallejo, CA.

Partners: Ray Huber, Ecosystems Manager, Sequoia National Forest, Steve Pintek, Forester, Sequoia National Forest, Al Vazquez, Silviculturist, Lassen National Forest

Methods

Task 1. - Locate and tag 10,800 trees for inclusion in the study.

Individual trees will serve as plot and will be located within fires that burned in California during 2002 (We advocate using fires from the same year as a way of eliminating differences attributable to conditions in different years). Table 1 contains categories for the dependent variables of interest. Each unique combination of these categories defines a population for which we want to assign a probability of mortality at the end of the 3rd growing season after wildfire. A sample of 30 trees in each population is desired. Therefore, the total number of trees desired for this study is 30 samples times 4 species times 3 diameter classes times 6 crown kill classes times 5 cambium damage classes = 10,800 trees. We will strive to find as many of this desired number as practical in the 2003 field season.

The selected trees will be monumented by painting a number at breast height that corresponds with a metal numbered tag near ground level. Trees will be double banded around the entire circumference to facilitate relocation. A stem map will be created to illustrate tree locations within the study area. GPS units will be used as needed. The selected trees will be protected for

the duration of this study from management activities that could influence the results.

Table 1. Criteria for tree selection.

SPECIES	DBH classes	Crown Kill Percentages	Cambium Damage Ratings
Ponderosa pine	10" – 20"	< 30	0
Incense cedar	20" – 30"	51-60	1
White fir	30" +	61-70	2
		71-80	3
		81-90	4
		91-100	

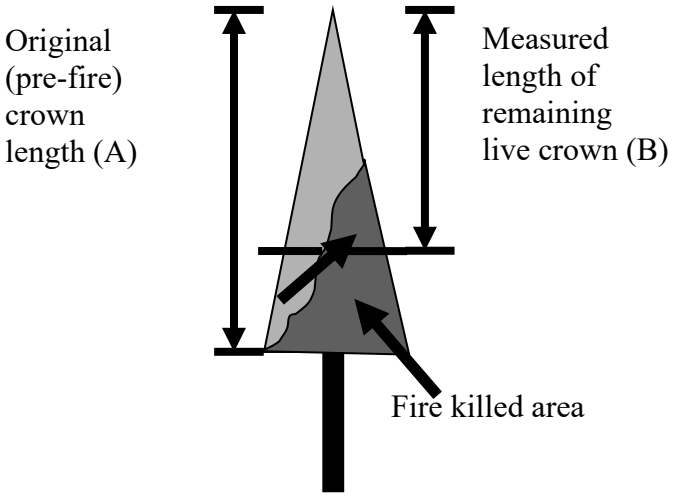
Individual tree information will include species, dbh, tree height, and percent live crown length (pre-fire). Fire damage information to be collected for each tree will include percent length crown kill, a cambium damage rating, and bark char information. Any signs of insect activity such as frass, boring dust, or pitch tubes will also be noted. General site information will be collected as appropriate.

Determining Crown Damage

Method 1.

The amount of crown kill will be determined by measuring the original (pre-fire) crown height (or length) and then measuring the height (or length) of remaining live crown to calculate the percent remaining live crown (Figure 1). Crown kill is the percent of original live crown minus the percent of remaining (post-fire) live crown.

Figure 1. Linear measurement of crown kill.



B/A*100 = Percent remaining live crown.

Method 2.

Percent volume of crown killed will be determined by looking at the overall appearance of the crown and estimating the percent of the pre-fire crown volume that was killed by the fire.

Determining Cambium Damage Rating

The cambium damage rating will be determined by drilling into the cambium close to ground-line at four evenly spaced locations around the tree using a power drill with a 1" bit hole saw bit to see if the cambium is live (L) or dead (D). Live tissue feels moist, soft, and spongy. The color varies by species, but is generally a light, peachy shade. Dead cambium is typically hardened and has a darker appearance. Cambium may also be resin impregnated, due to high internal temperatures that cause the resin ducts in the tree to burst. Individual tree ratings will be 0-4, the total of all dead samples.

Determining Bark Char

Bark char is an indicator of the length of time the tree bole was exposed to flames and high temperatures from the fire. This correlates to the heat pulse into the tree. The bark acts as an insulator of the cambium. The thicker the bark, the longer the tree can be exposed to high temperature without killing the cambium. It takes about 20 minutes of exposure per 1 inch^2 of bark to kill the cambium. We do not expect this criterion to be included in the marking guidelines due to variability with interpretation among marking crews, however, it may be a criteria used in model development. Bark char will be determined following the methods in Ryan and Noste (1985). Table 2 shows the bark char class descriptions. Obtaining bark char information for each quadrant, corresponding to a drill sample point, is a non-destructive way estimating cambium injury between the drill sample points.

Table 2. Bark char class descriptions.

Unburned (U)	Not burned
Lightly charred (L)	Evidence of light scorching; can still identify species based on bark characteristics; bark is not completely blackened; edges of bark plates charred
Moderately charred (M)	Bark is uniformly black except possibly some inner fissures; bark characteristics still discernable
Deeply charred (D)	Bark has been burned into, but not necessarily to the wood; outer characteristics are lost

Determining insect attack.

Insect activity including an estimate of percent bole circumference with frass or boring dust and estimate of the number of bark beetle pitch tubes will be noted for each tree. Trees that have detectable diseases, pathogens or large "cat faces" from previous fires will not be included in the study.

Task 2. - Monitoring

The study will be implemented during the summer of 2003 and will continue for a minimum of two years. Individual trees will be monitored annually beginning in 2004 and 2005. The need for revisits beyond that will be determined at that time. Trees that die during the life of the study may be removed after annual data collection. FHP will notify the appropriate land manager regarding dead tree removal.

Task 3. - Data Analysis

Logistic regression and neural networks will be used to model white fir, yellow pine, and incense cedar response to fire. Models will be developed to predict the probability of mortality following fire. These models will then be used to develop post-fire salvage marking guidelines for use in Region 5 and may also be used to improve models used in the development of treatment prescriptions (e.g., FOFEM) and management policy (e.g., FFE-FVS).

Data Steward: FHP and RMRS will initiate data management and be responsible for data collection.

Reports: FHP will write annual monitoring reports and distribute as appropriate.

Literature Cited

Bevins, C.D. 1980. Estimating survival and salvage potential of fire-scarred Douglas-fir. USDA – Forest Service, Intermountain Forest & Range Experiment Station, Ogden, Utah. Research Note INT – 287. 8p.

Lynch, D.W. 1959. Effects of wildfire on mortality and growth of young ponderosa pine trees. USDA Forest Service. Int. Forest and Range Experiment Station, Ogden, UT. Res. Note INT-66. 8p.

Peterson, D.L. 1985. Crown scorch volume and scorch height: estimates of postfire tree condition. Can. J. For. Res. 15:596-598.

Ryan, K.C. 1983. Techniques for developing fire damage to trees. Pgs. 1-11 in Fire – Its Field Effects. J. Lotan ed. Intermountain Fire Council, Missoula, MT.

Ryan, K.C. 1998. Analysis of the relative value of morphological variables in predicting fire-caused tree mortality. In: Proceedings of the III International Conference on Forest Fire Research

and 14th Conference on Fire and Forest Meteorology: November 16-20, 1998, Coimbra, Portugal: vol. II. Coimbra Portugal: 1511-1526.

Ryan, K.C. 2000. Effects of fire injury on water relations of ponderosa pine. Pages 58-66 in W. Keith Moser and Cynthia F. Moser (eds.). Fire and forest ecology: innovative silviculture and vegetation management. Tall Timbers Fire Ecology Conference Proceedings, No. 21. Tall Timbers Research Station, Tallahassee, FL.

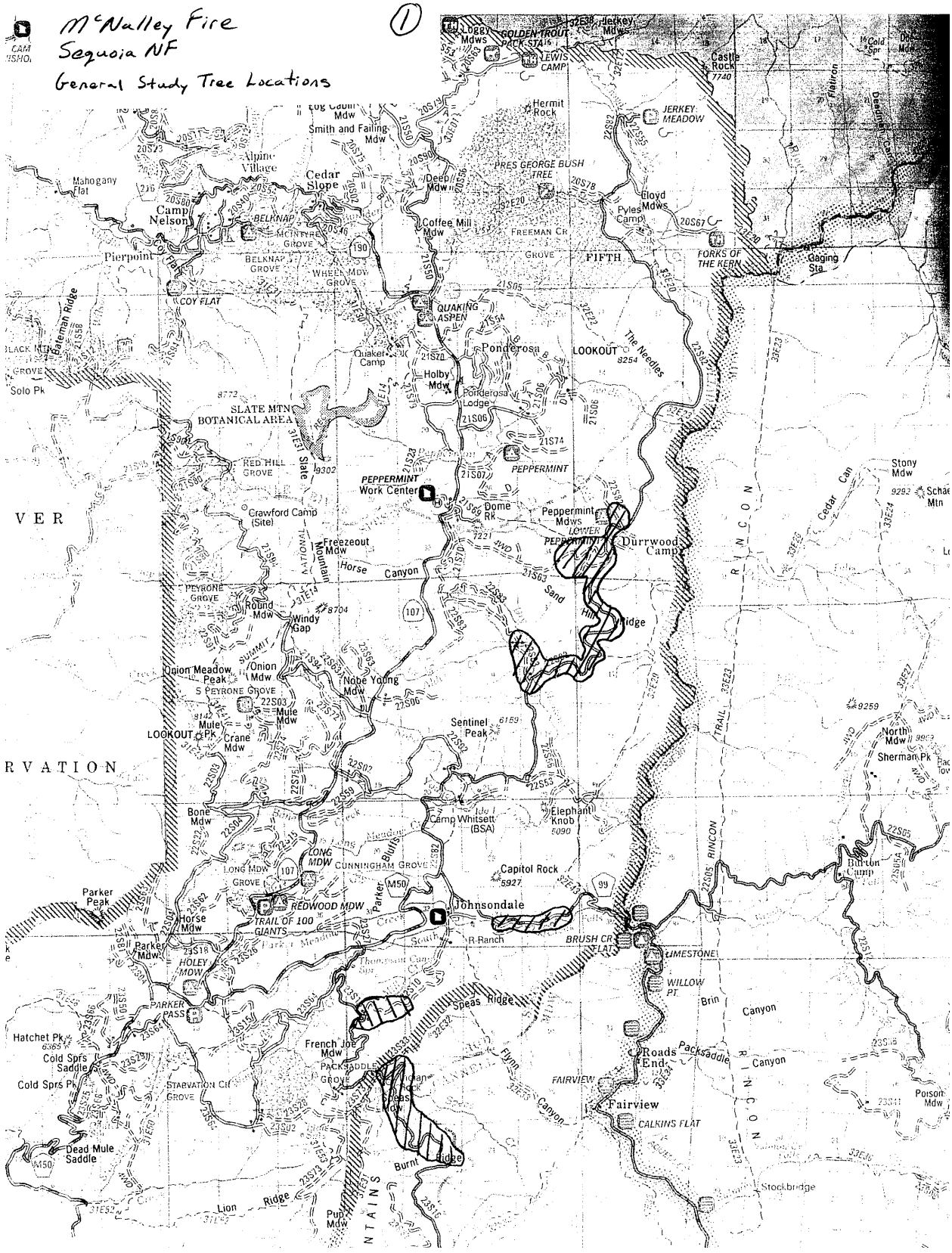
Ryan, K. C. and G. D. Amman. 1994. Interactions between fire-injured trees and insects in the greater Yellowstone area. p. 89-101. *In:* Plants and their environments: Proceedings of the first biennial scientific conference of the greater Yellowstone ecosystem. Yellowstone N.P., WY September 16-17,1991. Technical Report NPS/NRYELL/NRTR-93/XX.

Ryan, K.C. and W.H. Frandsen. 1991. Basal injury from smoldering fires in mature *Pinus Ponderosa* Laws. International Journal of Wildland Fire. 1(2): 107-118.

Ryan, K. C. and N. V. Noste. 1985. Evaluating prescribed fires. p. 230-237. *In:* Proceedings – symposium and workshop on wilderness fire. Missoula, MT November 15-18, 1983. USDA Forest Service GTR INT-182.

Ryan, K. C. and E. D. Reinhardt. 1988. Predicting postfire mortality of seven western conifers. Can. J. For. Res. 18:1291-1297.

Wagener, W. W. 1961. Guidelines for estimating the survival of fire-damaged trees in California. USDA-FS, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA. Misc. Paper No. 60, 11 p.


McNalley Fire
Sequoia NF
General Study Tree Locations
①
Mahogany Flat
Alpine Village
Cedar Slope
Smith and Failing Mdw
Camp Nelson
Pierpoint
Coy Flat
Bateman Ridge
Solo Pk
Hermit Rock
JERKEY MEADOW
Castle Rock 7740
Floyd Mdws
Pyles Camp
Coffee Mill Mdw
FREEMAN CR
FIFTH
FORKS OF THE KERN
Gaging Sta
QUAKING ASPEN
Quaker Camp
Ponderosa
LOOKOUT 8254
The Needles
Holby Mdw
Ponderosa Lodge
SLATE MTN BOTANICAL AREA
RED HILL GROVE
PEPPERMINT Work Center
Crawford Camp (Site)
Dome RK
Peppermint Mdws
Durrwood Camp
Stony Mdw
Cedar Can
Freezeout Mdw
Horse Canyon
Sand Hill Ridge
PEYRONE GROVE
Round Mdw
Windy Gap
Onion Meadow Peak
Onion Mdw
Nobe Young Mdw
S PEYRONE GROVE
Mule Mdw
LOOKOUT Pk
Crane Mdw
Sentinel Peak 8169
North Mdw
Sherman Pk
Bone Mdw
Camp Whitsett (BSA)
Elephant Knob 5090
LONG MDW CUNNINGHAM GROVE
Capitol Rock 5927
Burton Camp
Parker Peak
REDWOOD MDW
TRAIL OF 100 GIANTS
Johnsondale
R-Ranch
BRUSH CR FLAT
LIMESTONE
Horse Mdw
Parker Mdw
HOLEY MDW
WILLOW PT
Brin Canyon
PARKER PASS
Speas Ridge
Hatchet Pk
Cold Spgs Saddle
Cold Spgs Pk
French Joe Mdw
PACK SADDLE GROVE
STARVATION CR GROVE
Roads End
Packsaddle Canyon
FAIRVIEW
Fairview
CALKINS FLAT
Poison Mdw
Dead Mule Saddle
Burnt Ridge
Lion Ridge
Pup Mdw
Stockbridge
RINCON
SUMMIT TRAIL
Jerkey Mdw
Deer Mdws
GOLDEN TROUT PACK STA
LEWIS CAMP
PRES GEORGE BUSH TREE
Deep Mdw
Cold Spr
Flatiron
Deadman Creek
Schaeffer Mtn
VER
RVATION
NTAINS

McNalley Fire
Sequoia NF
General Study Tree Locations

(2)